PROCEEDINGS

OF THE

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SIXTY-SEVENTH SESSION.

Monday, 4th December 1848.

Sir T. MAKDOUGALL BRISBANE, Bart., in the Chair.

The following Communications were read:—

1. Geological Notes on the Valleys of the Rhine and Rhone. By Robert Chambers, F.R.S.E.

The principal part of this paper was devoted to a description of alluvial terraces, as seen along the banks of the Rhine at Bonn, Mainz, and Basle, and in the valley of the Arve, the well-known tributary of the Rhone. These terraces, which rise high above the reach of the present river, yet slope in the same direction. The intermediate hollow or trough in which the river runs, has evidently been cut out of what was at first an entire sloping sheet of detrital matter, filling the valley from side to side up to a certain height. At the lower part of the Arve valley, the detrital matter has been discharged across the valley of the Rhone, so as to form a barrier for the Lake of Geneva.

At Vevay, on this lake, there is a short side valley, containing tiers of sloping terraces, which have been called ancient moraines, but are set down in this paper as deltas or river alluvia, marking the stages of the subsidence of a recipient body of water. The chief of these terraces are respectively about 165 and 442 feet above the present level of the lake.

To illustrate the formation of these terraces and deltas, reference was made to the recently-drained Lake of Lungern, in Unterwalden The inpour of mountain-streamlets into such lakes is over a sloping sheet of detritus, extending from the base of the mountains to

the edge of the lake, and passing on in the same direction, below the lake, till, owing to the check of the water, it comes to an abrupt termination, and stoops suddenly down. In the case of the Lake of Lungern, on the water being withdrawn, the stream, no longer received into a body of still water, has begun to cut down its delta, as the Niagara River cuts through the strata on which it runs, until a deep channel is formed all the way back to the mountains, the removed matter being, of course, carried forward into the receded waters of the lake. This the author of the paper regarded as an explanation of the formation of alluvia in valleys, and their subsequent intersection. The detritus was received into a body of water occupying the valley ; on that being withdrawn, the river was allowed to cut down and form a channel for itself in the alluvial sheet. A number of reasons were adduced for believing that, in general cases, this recipient body of water was the sea.

A description was given of an ancient lake-bed in the vale of Chamouni, the barrier of which was the right side moraine of the anciently more extended Glacier des Bois or Mer de Glace. Some notices were appended regarding smoothings of fixed surfaces and zones of erratic blocks in Switzerland, and an endeavour was made to establish the probability of icebergs borne on the sea having been concerned in producing some of those phenomena. It was particularly remarked that the zone of blocks at Monthey was just about the same height above the present level of the sea (1670 feet) as the uppermost of the terraces at Vevay; while M. Saussure had found traces of running water on Mont Salève, at the height of the celebrated erratics above Neufchâtel.

These facts were not presented in opposition to the doctrine of a former greater extent for the glaciers, which was, on the contrary, admitted, though not to the extent demanded by some previous observers. Different agencies, or the same agencies differently applied, might, the author thought, often lead to nearly similar effects.

2. On the Classification of Colours. By Professor J. D. Forbes.

As the reading of this paper was only commenced at this meeting, the abstract is deferred until the conclusion.

The following Donations to the Library were announced :—

Ancient Sea-Margins. By Robert Chambers, Esq. 8vo.—*By the Author.*

Account of the Skerryvore Lighthouse; with Notes on the Illumination of Lighthouses. By Alan Stevenson, LL.B. 4to.—*By the Author.*

Reduction of Greenwich Lunar Observations, under the superintendence of G. B. Airy, Esq. 1750–1830. Vols. I. & II. 4to. —*By the Observatory.*

Modern Languages; their Historical Development, and claims, as a branch of Academical Study. By Sigismund Wallace, Dr Ph. 12mo.—*By the Author.*

Mémoires de la Société de Physique, et d'Histoire Naturelle de Genève. Tom. XI., 2me Partie. 4to.—*By the Society.*

Scheikundige Onderzoekingen, gedaan in het Laboratorium der Utrechtsche Hoogeschool. 4de Deel, 5de Stuk. 8vo.—*By the University.*

Transactions of the American Philosophical Society. N. S., Vol. X., Part 1. 4to.

Proceedings of the American Philosophical Society. Vol. IV., Nos. 36–39. 8vo.—*By the Society.*

American Journal of Science and Arts. Conducted by Professors Silliman and Dana. 2d Ser., No. 14. 8vo.—*By the Editors.*

Annals of the Lyceum of Natural History of New York. Vol. IV., Nos. 8 and 9. 8vo.—*By the Lyceum.*

Journal of the Asiatic Society of Bengal. Edited by the Secretaries. Nos. 185, 186, 187; (N. S., Nos. 12, 13, 14.) 8vo.—*By the Editors.*

Journal of the Indian Archipelago, and Eastern Asia. Vol. I., Nos. 4–6. Vol. II., Nos. 1 and 2. 8vo.—*By the Editor.*

Quarterly Journal of the Chemical Society of London. Edited by Edmund Ronalds, Ph. D. No. 182. 8vo.

Memoirs and Proceedings of the Chemical Society. Part 23. 8vo. —*By the Society.*

Journal of the Statistical Society of London. Vol. XI., Part 2. May 1848. 8vo.—*By the Society.*

Quarterly Journal of the Geological Society. No. 14. 8vo.—*By the Society.*

Journal of the Royal Geographical Society of London. Vol. XVIII., Part 1. 1848. 8vo.—*By the Society.*

Fifteenth Annual Report of the Royal Cornwall Polytechnic Society. 1847. 8vo.—*By the Society.*

Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland. No. 21, N. S. July 1848. 8vo. —*By the Society.*

Address delivered at the Anniversary Meeting of the Geological Society of London, 18th February 1848. By Sir H. T. De La Bêche. 8vo.—*By the Society.*

Memoirs of the Literary and Philosophical Society of Manchester. N. S., Vol. VIII. 8vo.—*By the Society.*

Histoire des Révolutions de la Philosophie en France. Par le Duc De Caraman. Paris, 1845–8. 3 tom. 8vo.—*By the Author.*

Flora Batava. Parts 144, 145, 146. 4to.—*By the King of Holland.*

Transactions of the Royal Irish Academy. Vol. XXI., Part 2. 4to.—*By the Academy.*

Report of the British Association for the Advancement of Science, for 1847. 8vo.—*By the Association.*

Astronomical Observations made at the Royal Observatory, Greenwich, in the year 1846, under the superintendence of G. B. Airy, Esq. 4to.—*By the Observatory.*

Journal of the Asiatic Society of Bengal. Edited by the Secretaries. N. S., Nos. 15 and 16. 8vo.—*By the Editors.*

Journal of the Royal Asiatic Society of Great Britain and Ireland, 1848. No. 18. 8vo.—*By the Society.*

Geology of the Silurian Rocks in the Valley of the Tweed. By James Nicol. 8vo.—*By the Author.*

Annals of the Lyceum of Natural History of New York. Vol. IV., Nos. 10, 11. 8vo.—*By the Lyceum.*

Journal of the Statistical Society of London. Vol. XI., Part 3. 8vo.—*By the Society.*

Flora Batava. Parts 152 and 153. 4to.—*By the King of Holland.*

Philosophical Transactions, Royal Society of London, 1848. Part 1. 4to.—*By the Society.*

Annales de l'Observatoire Royale de Bruxelles. Tom. VI. 4to.—*By the Observatory.*

Mémoires Couronnés et Mémoires des Savants Etrangers, publiés par l'Académie Royale des Sciences, &c., de Belgique. Tom. XXII. 1848. 4to.

Mémoires de l'Académie Royale des Sciences, &c., de Belgique. Tom. XXI. and XXII. 1848. 4to.

Bulletins de l'Académie Royale des Sciences, &c., de Belgique. Tom. XIV., Part 2 ; Tom. XV., Part 1. 8vo.

Annuaire de l'Académie Royale des Sciences, &c., de Belgique. 1848. 12mo.—*By the Academy.*

Annuaire de l'Observatoire Royale de Bruxelles. Par A. Quételet. 1848. 12mo.

Catalogue des Livres de la Bibliothèque de l'Observatoire Royale de Bruxelles. 1847. 8vo.—*By the Observatory.*

Bulletins des Séances de la Société Vaudoise des Sciences Naturelles, Nos. 16 and 17. 8vo.—*By the Society.*

Proceedings of the Royal Society, 1847, No. 70. 8vo.—*By the Society.*

Address of the Marquis of Northampton to the Royal Society, June 9, 1848. 8vo.—*By the Society.*

Observations des Phénomènes Périodiques. (Acad. R. de Belgique, Extrait du Tom. XXI., des Mémoires.) 4to.

Du Système Social et des lois qui le régissent, par Ad. Quételet. Paris, 1848. 8vo.

Rapport à le Ministre de l'Interieur, sur l'état et les travaux de l'Observatoire Royale de Bruxelles. 1847. 8vo.—*By M. Quételet.*

Bulletin de la Société Impériale des Naturalistes de Moscou, 1847, No. 2. 8vo.—*By the Society.*

Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland. N. S., No. 22. October 1848. 8vo.—*By the Society.*

Athenæum (London) Rules and Regulations, List of Members, and Donations to the Library, 1846 ; with Supplement for 1847. 12mo.—*By the Athenæum.*

Proceedings of the American Philosophical Society. Vol. V., No. 40. January—April 1848. 8vo.—*By the Society.*

Journal of the Asiatic Society of Bengal. Edited by the Secretaries. No. 191, June 1848. 8vo.—*By the Society.*

Proceedings of the American Academy of Arts and Sciences. Vol. I. May 1846 to May 1848. 8vo.—*By the Society.*

American Journal of Science and Arts. Conducted by Professors Silliman and Dana. Vol. VI. No. 17. 8vo.—*By the Editors.*

Nieuwe Verhandelingen der Eerste Klasse van het Koninkl. Nederländsche Instituut te Amsterdam. 13e Deel. 4to.

Tijdschrift voor de Wis-en Natuurkundige Wetenschappen, uitgegeven door de Eerste Klasse van het K. Nederländsche Instituut van Wetenschappen. Eerste Deel. 1, 2, 3, Aflevering. 1847–8. 8vo.—*By the Society.*

Journal of the Indian Archipelago and Eastern Asia. Supplement to No. VI. of Vol. I.; Vol. II., Nos. 3, 4, 5, 6, 7, 8. 8vo. —*By the Editors.*

The Ethnological Journal. No. 5. October 1848. 8vo.—*By the Editor.*

Reprint of the Report of the Trustees of the Massachusetts General Hospital, with a History of the Ether Discovery, and Dr Morton's Memoir to the French Academy. Edited by R. H. Dana, jun. 8vo.—*By the Editor.*

Magnetical and Meteorological Observations made at the Royal Observatory, Greenwich, in the year 1846, under the direction of G. B. Airy, Esq. 4to.—*By the Observatory.*

Bulletin des Séances de la Société Vaudoise des Sciences Naturelles. No. 18. 8vo.—*By the Society.*

Proceedings of the Literary and Philosophical Society of Liverpool, during the 36th Session. No. 4. 8vo.—*By the Society.*

Proceedings of the Royal Astronomical Society. Vol. VIII. Supplement, No. 9. 8vo.—*By the Society.*

On the Manufacture of Artificial Stone with a Silica Base. By Frederick Ransome. 8vo.—*By the Author.*

Twenty-Eighth Report of the Leeds Philosophical and Literary Society. 1847–8. 8vo.—*By the Society.*

The Ethnological Journal. No. 6. 8vo.—*By the Editor.*

Astronomical Observations made at the Observatory of Cambridge, by the Reverend James Challis. Vol. XV. 1843. 4to.—*By the Observatory.*

Annuaire Magnétique et Météorologique du Corps des Ingénieurs des Mines, ou Recueil d'Observations Magnétiques et Météorologiques, faites dans l'entendue de l'Empire de Russie. Par A. T. Kupffer. Année 1845. Nos. 1 and 2. 1848. 4to.

Résumés des Observations Météorologiques faites dans l'entendue de l'Empire de Russie. Par A. T. Kupffer. 1er Cahier. 4to.—*By M. Kupffer.*

An Introduction to the Birds of Australia. By John Gould, F.R.S. 8vo.—*By Professor Forbes.*

Journal of the Asiatic Society of Bengal. Edited by the Secretaries. No. 161. May 1848. 8vo.—*By the Society.*

Journal of the Asiatic Society of Bengal. Edited by the Secretaries. No. 193. July 1848. 8vo.—*By the Society.*

Journal of the Statistical Society of London. Vol. XI., Part 4. 8vo.—*By the Society.*

Monday, December 18, 1848.

The Very Rev. Principal LEE, D.D., in the Chair.

The following communications were read :—

1. Description of a Mud-slide at Malta. By A. Milward, Esq. Communicated by the Secretary.

A large quantity of mud, dredged up from the harbour of Valetta, having been deposited on a piece of slightly-inclined ground, and having been subsequently moistened to an excessive extent by rain, and by the overflow of a neighbouring tank, the upper parts began to flow down over the lower and the original boundary, in six distinct streams ; this separation being apparently caused by the difference of resistance and level of the under stratum.

These streams exhibited, to a remarkable degree, all the phenomena of glaciers, and thus tended greatly to confirm the theory which looks upon them not as a solid, or a collection of solid masses, but as a viscous fluid. Curved bands of dark and light mud were seen crossing the streams similarly with Professor Forbes's "dirt-bands" on the glaciers; and the crevasses had their counterparts in the cracks in the mud.

2. An Attempt to explain the "Dirt-Bands of Glaciers." By A. Milward, Esq.

A second mud-slide having occurred at Malta, with more marked features than the first, Mr Milward was enabled to ascertain that the curved bands of dark and light mud are not only accompanied by a

difference of elevation in those parts, but that these wrinkles are the *cause* of that difference of colour; the more watery parts draining from the ridge, leave that rough, and form a smooth alluvium in the hollow.

Applying these facts to the glaciers, Mr Milward supposes that the dirt-bands, *i.e.* the bands of alternate compact and porous ice, must be accompanied by a similar difference of elevation, which, though destroyed by the action of the sun on the lower parts, may yet be visible near the origin of the glaciers in the early spring; and he further supposes that the bands may be formed, in the first instance, by the irregular descent of the nevé in winter and summer, so that they become in fact the annual rings of the glacier, shewing its age and rate of increase.

3. On the rate of Progression of the Himalayan Glaciers. By Lieutenant R. Strachey, Bengal Engineers.

Mr Strachey's letter contained some interesting observations which he has been making on the motions of the glaciers in the Himalayan mountains; and his measures, conducted on the plan of Professor Forbes in the Alps, are the earliest that have been taken in Asia. The Pinduree glacier, on which the observations were made during cold weather, was found to move 3 feet 1 inch in 5 days at the centre, and at the sides about 1 foot 5 inches.

Lieutenant Strachey's former Researches on the Glaciers of the Kumaon Himalaya (published in one of the Indian Journals), have satisfactorily proved the existence of glaciers in lat. 30° 20′, which present in detail all the phenomena of those of Europe.

4. Observations on the preceding Communications, and especially on the cause of the Annual Rings of Glaciers. By Professor Forbes.

Professor Forbes stated that Mr Milward's shrewd suspicion of the bands of ice of different consistence being accompanied also by wrinkles or elevations, had been discovered by himself some years before, at the very place and time pointed out as most likely; and he shewed that, while there is a tendency in a tenacious viscous fluid to produce wrinkles, under pressure capable of effecting detrusion,

even where the supply of the fluid is uniform; that this quality is greatly increased when the supply of the fluid is by fits, as it is in fact at the head of this glacier, where the quasi-hydrostatic pressure from behind, combined with the frontal resistance, produces a thickening, or convex lip or wrinkle.

He likewise mentioned the analogous instance of the production of equidistant wrinkles in the sides of railway banks, from mere pressure above; and more particularly in turnings of coarse malleable iron, where, though the detruding force is constantly equal, still detrusion takes place at intervals, forming in the shaving so many wrinkles, by which frontal resistance too, it is thickened, and consequently shortened, similarly with the mechanism of the glacier.

The Astronomer-Royal, Mr Airy, then favoured the meeting with a discourse on the telescopes of Lord Rosse and Mr Lassel, specially pointing out those parts in the progress of construction, in which these two eminent mechanists and opticians differed, and sometimes widely, from each other; though they have both arrived equally, at last, at the same goal of all but perfection.

The following Donations to the Library were announced:—

Die Fortschritte der Physik im Jahre 1846. Dargestellt von der Physikalischen Gesellschaft zu Berlin. 2 Jahrgang. 8vo.—*By the Society.*

Medico-Chirurgical Transactions. Vol. XXXI. 1848. 8vo.—*By the Society.*

Troisième, Cinquième, Sixième, et Septième Mémoires sur l'Induction. Par M. Elie Wartmann. 8vo.—*By the Author.*

The Ethnological Journal. No. 7. Dec. 1, 1848. 8vo.—*By the Editor.*

Tuesday, January 2, 1849.

Dr CHRISTISON in the Chair.

The following Communications were read:—

1. An Account of Carnot's Theory of the Motive Power of Heat,* with Numerical Results deduced from Regnault's Experiments on Steam.† By Professor William Thomson, of Glasgow.

The questions to be resolved by a complete theory of the motive power of heat, are the following:—

I. What is the precise nature of the thermal agency by means of which *mechanical effect* is to be produced, without effects of any other kind?

II. How may the amount of this thermal agency necessary for performing a given quantity of work be estimated?

I. On the nature of Thermal Agency, considered as a Motive Power.

The whole theory rests on a principle generally admitted as an axiom, which Carnot expresses in the following terms:‡—

"In our demonstration, we tacitly assume that after a body has experienced a certain number of transformations, if it be brought identically to its primitive physical state as to density, temperature, and molecular constitution, it must contain the same quantity of heat as that which it initially possessed; or, in other words, we suppose that the quantities of heat lost by the body under one set of operations, are precisely compensated by those which are absorbed in the others. This fact has never been doubted; it has at first been ad-

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* Published in 1824, in a work entitled, "Réflexions sur la Puissance Motrice du Feu," by Mons. S. Carnot. An account of Carnot's theory is also published in the *Journal de l'Ecole Polytechnique*, vol. xiv., 1834, in a paper by Mons. Clapeyron.

† An account of the first part of a series of researches undertaken by Mons. Regnault, by order of the late French Government, for ascertaining the various physical data of importance in the theory of the steam-engine, has been recently published in the *Mémoires de l'Institut*, of which it constitutes the twenty-first volume (1847). The second part of the researches has not yet been published.

‡ The passage quoted in the text is translated from a note to p. 37, in Carnot's Treatise.

mitted without reflection, and afterwards verified in many cases by calorimetrical experiments. To deny it would be to overturn the whole theory of heat, of which it is a fundamental principle. It must be admitted, however, that the chief foundations on which the theory of heat rests would require a most attentive examination. Several experimental facts appear nearly inexplicable in the actual state of this theory."

Since the time when Carnot thus expressed himself, the necessity of a most careful examination of the entire experimental basis of the theory of heat has become more and more urgent. Especially all those assumptions depending on the idea that heat is a *substance* invariable in quantity, not convertible into any other element, and incapable of being *generated* by any physical agency; in fact, the acknowledged principles of latent heat, would require to be tested by a most searching investigation before they ought to be admitted, as they usually are, by almost every one who has worked on the subject, whether in combining the results of experimental researches or in reasoning *à priori*.

The extremely important discoveries recently made by Mr Joule, of Manchester, that heat is evolved in every part of a closed electric conductor, moving in the neighbourhood of a magnet;* and that heat

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* I cannot omit this opportunity of correcting an expression which I made use of in a note published in the Philosophical Magazine (vol. xxxiii., p. 315), in alluding to the *generation* of heat by such operations, which I inadvertently asserted to have been proved by "*known experiments*, adduced by Mr Joule." It is true that the *evolution* of heat in a fixed conductor, through which a galvanic current is sent from any source whatever, has long been known to the scientific world; but it was pointed out by Mr Joule that we cannot infer, from any previously published experimental researches, the actual *generation* of heat when the current originates in electro-magnetic induction, since the question occurs, *Is the heat which is evolved in one part of the closed conductor merely transferred from those parts which are subject to the inducing influence?* Mr Joule, after a most careful experimental investigation, with reference to this question, finds that it must be answered in the negative. (See a paper "On the Calorific Effects of Magneto-Electricity, and on the Mechanical Value of Heat; by J. P. Joule, Esq.;" read before the British Association at Cork, in 1843, and subsequently communicated by the author to the Philosophical Magazine, vol. xxiii., pp. 263, 347, 435.)

Before we can finally conclude that heat is absolutely generated in such operations, it would be necessary to prove that the inducing magnet does not become lower in temperature, and thus give compensation for the heat evolved in the

is *generated* by the friction of fluids in motion seem to overturn the opinion commonly held that heat cannot be *generated*, but only produced from a source where it has previously existed, either in a sensible or in a latent condition. In the present state of science, however, no operation is known by which heat can be absorbed into a body, without either elevating its temperature or becoming latent, and producing some alteration in its physical condition; and the fundamental axiom adopted by Carnot may be considered as still the most probable basis for an investigation of the motive power of heat; although this, and with it every other branch of the theory of heat, may ultimately require to be reconstructed on another foundation, when our experimental data are more complete. On this understanding the author of the present paper refers to Carnot's fundamental principle, as if its truth were thoroughly established.

If we consider any case in which mechanical effect is obtained from a thermal origin, by means of the alternate expansions and contractions of any substance whatever, and follow a perfectly rigorous process of reasoning indicated by Carnot, we arrive at the following conclusion, by which the first proposed question is answered:—

The thermal agency by which mechanical effect may be obtained, is the transference of heat from one body to another at a lower temperature.

II. On the measurement of Thermal Agency, considered with reference to its equivalent of mechanical effect.

The criterion of what may be called *a perfect thermo-dynamic engine* is thus stated:—

A perfect thermo-dynamic engine is such, that, whatever amount of mechanical effect it can derive from a given thermal agency, if an equal amount be spent in working it backwaxds, an equal reverse thermal effect will be produced.

Any two perfect engines, however different in their constructions,

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conductor. I am not aware that any examination, with reference to the truth of this conjecture, has been instituted; but in the case when the inducing body is a pure electro-magnet (without any iron) the experiments actually performed by Mr Joule render the conclusion probable, that the heat evolved in the wire of the electro-magnet is not affected by the inductive action otherwise than through the reflected influence, which diminishes the strength of its own current.

or in the physical media employed, must derive the same equivalent of mechanical effect from a given thermal agency. Carnot describes a steam-engine and an air-engine, each of which satisfies the criterion laid down above (the construction being however in each case, practically impossible); and he shews how, with certain physical data, with reference to steam in one case, and with reference to air or any gas in the other, the equivalent of mechanical effect, derivable from a given thermal agency, may be calculated. Thus, if M denote the amount of mechanical effect due to the *descent* of H units of heat (or *caloric*) from a body A at the temperature S, through the medium of a perfect engine of any kind, to a body B at the temperature T, we find, by Carnot's method of reasoning,

$$M = H\int_T^S (1-\sigma)\frac{\frac{dp}{dt}}{k}dt = E\,p_0v_0\int_0^H\int_T^S \frac{1}{v}\frac{dv}{dq}dt\,dq$$

In the first expression, deduced by the theory of the steam-engine, p denotes the pressure, σ the density, and k the latent heat of a unit of volume of saturated vapour from any liquid, at the temperature t. In the second, deduced by the theory of the air-engine, E denotes the coefficient of expansion (·00366, if the centigrade scale of the air-thermometer be adopted) of a gas; p_0 the pressure of a given mass of gas when reduced to the freezing point of temperature, and to the volume v_0; p the pressure of the same gaseous mass when occupying the volume v, at the temperature t; q the quantity of heat which must be added to the same mass to raise its temperature from 0 to t, when its volume is at the same time changed from v_0 to v; and $d\,q$ the heat absorbed by the gas when, with its temperature kept at t, its volume is augmented from v to $v+d\,v$.

Hence the mechanical effect to be obtained by the *letting down* of a unit of heat from a body A, to a body B at a lower temperature t, if the interval between their temperatures be an extremely small quantity τ, will be, according to the first expression:

$$(1-\sigma)\frac{\frac{dp}{dt}}{k}\,\tau,$$

and, according to the latter,

$$\frac{E\,p_0v_0}{H}\int_0^H \frac{1}{v}\frac{dv}{dq}dq\,.\,\tau$$

If H be taken infinitely small, the latter expression becomes

$$\mathrm{E}\, p_0 v_0 \frac{1}{v} \frac{dv}{dq} \cdot \tau.$$

Hence, if $\mu\tau$ denote the mechanical effect due to the descent of one unit of heat from A at the temperature $t+\tau$ to B at the temperature t, we have

$$\mu = (1-\sigma) \frac{\frac{dp}{dt}}{k} = \mathrm{E}\, p_0 v_0 \frac{1}{v} \frac{dv}{dq}.$$

The value of μ (" Carnot's coefficient"), which is independent of the nature of the liquid or gas employed, may be determined for an assigned temperature, by means of observations upon any gas, or any liquid and its vapour. The most complete series of experiments from which the values of μ at different temperatures may be deduced, are those by means of which Regnault has determined the latent heat of a given weight, and the pressure, of saturated steam, at all temperatures between 0° and 230°. Besides these data, however, the density of saturated vapour must be given, in order that k, the latent heat of a unit of volume, may be calculated from Regnault's determination of the latent heat of a given weight. Between the limits of 0° and 100°, it is probable, from various experiments which have been made, that the density of vapour follows very closely the simple laws which are so accurately verified by the ordinary gases;* and thus it may be calculated from Regnault's table, giving the pressure at any temperature within those limits. Nothing as yet is known with accuracy as to the density of saturated steam between 100° and 230°, and we must be contented at present to estimate it by calculation from Regnault's table of pressures; although, when accurate experimental researches on the subject shall have been made, considerable deviations from the laws of Boyle and Dalton may be found.

Such are the experimental data on which the calculation of the mean values of μ, for the successive degrees of the air-thermometer from 0° to 230°, at present laid before the Royal Society, is founded.

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* This is well established by experiment, within the ordinary atmospheric limits, in Regnault's *Etudes Météorologiques*, in the *Annales de Chimie*.

The unit of length adopted is the English foot; the unit of weight, the pound; the unit of work, a "foot-pound;" and the unit of heat, that quantity which, when added to a pound of water at 0°, will produce an elevation of 1° in temperature. In making the calculation, the factor σ, in the expression for μ, which for all temperatures between 0° and 100° is less than $\frac{1}{1700}$, is neglected. The mean value of $\frac{dp}{dt}$ for any degree of the scale is found to a sufficiently high degree of approximation by merely taking the difference, the pressures given by Regnault at the temperatures immediately above and below it; and, to complete the calculation on the same system, the denominator of the fraction is taken as the mean value of k for that degree. The amount of mechanical effect due to the descent of a unit of heat through the nth degree of the scale, will be simply the nth value of μ in the table thus calculated.

The following abstract of the table, exhibits the sum of the first twenty values of μ, of the second twenty, of the third twenty, and so on; as well as the first value, the twenty-first, the forty-first, &c.

Mean values of μ for Cent. degrees of the Air-thermometer.		Sums of values of μ for intervals of 20°.	
No. on the scale.	Ft. lbs.		Ft. lbs.
1	5·12	From 1 to 20	99·8
20	4·85	... 21 ... 40	94·2
40	4·57	... 41 ... 60	88·8
60	4·31	... 61 ... 80	83·9
80	4·09	... 81 ... 100	79·7
100	3·90	... 101 ... 120	76·2
120	3·73	... 121 ... 140	73·3
140	3·60	... 141 ... 160	70·7
160	3·48	... 161 ... 180	68·5
180	3·37	... 181 ... 200	66·7
200	3·30	... 201 ... 220	65·2
220	3·23		
230	3·19		

As an example of the usefulness of these tables, let it be required to find the amount of mechanical effect produced by a steam-engine working with perfect economy, for each unit of heat which, after en-

tering the water of the boiler, is *let down* through the engine to the condenser, and there evolved. The "thermal agency" here is a unit of heat let down from a body at the temperature of the water in the boiler to another at the temperature of condensation, and the "mechanical effect," therefore, cannot be determined, unless those temperatures be given. Let us suppose then, in a particular engine, that the water of the boiler is at 120°, and the condenser at 40°, during the working of the engine. The required mechanical effect, calculated by adding the "sums" in the preceding table for all the intervals from 40° to 120° is found to be 328·6 foot-pounds.

2. Theoretical Considerations on the Effect of Pressure in lowering the Freezing-Point of Water. By James Thomson, Esq., jun., Glasgow. Communicated by Professor W. Thomson.

At the commencement of this paper the two following propositions are laid down:

I. That water at the freezing-point may be converted into ice by a process solely mechanical, and yet without the final expenditure of any mechanical work.

II. That the freezing-point of water must become lower as the pressure to which the water is subjected is increased.

The first of these is given as being interesting in itself, and as having been the original means of suggesting the second to the author. It may be deduced directly by the application to the freezing of water of the principle developed by Carnot, that no work is given out when heat passes from one body to another without a fall of temperature; or rather by the application of the converse of this, which, of course, equally holds good,—namely, that no work requires to be expended to make heat pass from one body to another at the same temperature. The first being established, the reasonableness of the second will readily be admitted; because the ordinary supposition of the freezing-point being constant, would involve the absurdity of a perpetual motion (or, more strictly, a perpetual source of mechanical work) being possible. For if a quantity of water were enclosed in a vessel with a moveable piston and frozen without the expenditure of work, the motion of the piston consequent on the expansion being resisted by pressure, mechanical work would be given out; and there would be no expenditure of any thing whatever to serve as an equivalent for this mechanical work given out, because

the water, after having been frozen, might be again melted, and so reduced to its original state, without the expenditure of work, according to the principles of Carnot already referred to. By the continued repetition, with the same mass of water, of the processes thus indicated, an unlimited quantity of work might be developed out of nothing, which is impossible. It, therefore, appears that if the water be made to perform work while freezing, either *work* or some equivalent agency must have been expended in freezing it. Now, the only way of accounting for this expenditure is by the assumption of the second proposition.

The fact of the lowering of the freezing-point by pressure being demonstrated by the method of which an outline has just been given, it becomes desirable, in the next place, to find what is the freezing-point of water for any given pressure. The most obvious way to determine this would be by direct experiment with freezing water. This experiment has, however, not as yet been made; and it would be difficult to make it with the precision which would be desirable, since the variation to be appreciated is extremely small; so small, indeed, as to afford sufficient reason for its existence never having been observed by any experimenter. The exact amount of the variation may, however, be deduced in a different way from experimental data, of which we are already in possession. These data are (1.), The known expansion of water in freezing; and (2.), The quantity of work given out by a unit of heat in descending through a degree near the freezing-point, which has been deduced from the experiments of Regnault on steam, and has been already laid before the Royal Society, in a paper by Professor William Thomson. The desired result is expressed in the formula,

$$t = {\cdot}0072\,P,$$

in which P is the pressure above the first atmosphere, expressed in atmospheres as units, to which the water is subjected, and t the lowering of the freezing-point, expressed in degrees centigrade, produced by the addition of that pressure. This formula may be applied for any pressure from nothing up to many atmospheres.

The following Donations to the Library were announced :—

The Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland. No. 23, N. S. 8vo.—*By the Society.*

Description de l'Observatoire Astronomique central de Pulkova. Par F. G. W. Struve. 2 tom. fol.

Beobachtungen des Halleyschen Cometen bei seinen erscheinen in Jahre 1835, auf der Dorpater Sternwarte angestellt von F. G. W. Struve. fol.

Stellarum Duplicium et Multiplicium Mensuræ Micrometricæ per Magnum Fraunhoferi Tubum, annis a 1824 ad 1827, &c. Auctore F. G. W. Struve. fol.

Additamentum in F. G. W. Struve Mensuras Micrometricas Stellarum Duplicium, &c. 4to.

Catalogus Novus Stellarum Duplicium et Multiplicium. Auctore F. G. W. Struve. fol.

Table des Positions Géographiques principales de la Russie. Rédigée par M. W. Struve. 4to.

Nouveaux Catalogues d'Etoiles Doubles. fol.

Catalogus Stellarum ex Zonis Regiomontanis. Auctore M. Weisse. 4to.

Expédition Chronométrique exécutée en 1843, entre Pulkova et Altona. fol.

———— Le même, exécutée en 1844, entre Altona et Greenwich. fol.

Notice sur l'Instrument des Passages de Repsold, &c. Par M. Struve. 4to.

Über die Flächeninhalt der 37 Westlichen Gouvernements und Provinzen des Europ. Russlands. Von F. G. W. Struve. 4to.

Resultäte der in dem Jahre 1816 und 1819, Ausgefürthen Astronomischen Trigonometrischen vermessung Leilands. Von W. Struve. 4to.

Astronomische Artsbestimmungen, in der Europaischen Turkei, &c. Von F. G. W. Struve. 4to.

Sur le Coefficient constant dans l'Observation des Etoiles fixés, &c. Par M. W. Struve. 4to.

Etudes d'Astronomie Stellaire. Par F. G. W. Struve. 1847, 8vo.

Resultate aus Beobachtungen des Polarsterns am erstelschen vertikalkreise der Pulkowaer Sternwärte. Von Dr C. A. F. Peters. 4to.

Von der Kleinen Arlenkungen der Lothlinie und des Niveans welche durch die Anziehungen der Sonne, &c. Von Dr C. A. F. Peters. 4to.

Über Prof. Mädlers Untersuchungen über die Eigenen Bevegungen der Fixsterne. Von Dr C. A. F. Peters. 4to.

Catalogus Librorum Speculæ Pulcovensis. 8vo.

By the Observatory of Pulkowa.

Mémoires de l'Académie Imp. des Sciences de St Pétersbourg. VIme Série. Tom. VI., Liv. 5 et 6 ; Tom. VII., Liv. 4, 5, et 6 ; et Tom. VII. ; (Tom. V., Liv. 1 et 2 ;) Tom. VIII., Liv. 1 et 2. 4to.

Recueil des Actes de la Séance publique de l'Académie Imp. des Sciences de St Pétersbourg, tenue le 29 Decembre 1845, et le 11 Janvier 1847. 4to.—*By the Academy.*

Acta Societatis Scientiarum Fennicæ. Tom. I. Tom. II., part. 1 and 2. 4to.

Notiser ar Sällskapets pro Fauna et Flora Fennica Förhandlingar. 1 Häftet. 4to.—*By the Society.*

Journal of the Asiatic Society of Bengal. No. 192. (Supp. No. for June 1848.) No. 194, Aug. 1848. 8vo.—*By the Society.*

Abhandlungen der K. Akademie der Wissenschaften zu Berlin. 1846. 4to.

Monatsbericht der K. Akademie der Wissenschaften zu Berlin. 1847, Juli—December; 1848, Januar—June. 8vo.—*By the Academy.*

Monday, January 15, 1849.

The Right Reverend Bishop TERROT, Vice-President, in the Chair.

The following Communications were read :—

1. On the Early History of the Air-Pump in England. By Dr George Wilson.

The early history of the English air-pump has been latterly allowed to fall into great confusion, so that the steps by which the in-

strument was improved, the periods at which those improvements were made, and the parties by whom they were effected, are all more or less confounded with each other, or mis-stated.

It is in connection with the double-barrelled air-pump, that the accepted history of the instrument is chiefly erroneous, but the mistakes made in reference to the more complex engine, have ultimately involved in confusion even the authentic records of the steps by which the earlier single-barrelled air-pump was improved, so that the account of its successive alterations must commence with its earliest and simplest construction.

The history of the English air-pump may be divided into four stages, three of which belong to the seventeenth century, and the fourth to the eighteenth. They are as follow, the dates, as given in the original authorities, being according to the Old Style:—

1659. The construction of a Pneumatical Engine consisting of a single-barrelled pump with a solid piston, moved by a rack and pinion, and a globular glass receiver directly communicating with the cylinder, which had an aperture closed and opened by a plug moved by the hand, and playing the part of a valve.

1667. The separation of the glass receiver from the cylinder, and introduction of the air-pump plate, on which bell-jars could be placed and used as receivers. The pump, still single-barrelled, and wrought by a rack and pinion, but with an aperture in the piston instead of in the cylinder, furnished with a moveable stopper.

1676. The introduction of a double-barrelled air-pump, with self-acting valves in the cylinders and pistons, and with piston-rods suspended at opposite ends of a cord passing over a pulley.

1704. The combination of the rack and pinion of the first and second air-pumps, with the two barrels, twin pistons, and self-acting valves of the third. The following are the more important details concerning those instruments.

Sometime before 1658, Boyle having heard, as he informs us (*Birch's Boyle*, Ed. 1772, vol. i., p. 6), of Guericke's air-pump and pneumatic experiments, had an exhausting engine of some kind constructed for him by Gratorix, a London instrument-maker of the time. No drawing or description of Gratorix's air-pump is extant, but it was so ineffective a machine that it was set aside as useless almost as soon as finished. Boyle had then recourse to Robert

Hooke, who constructed for him the air-pump which he employed in his first series of pneumatic researches. It appears to have been commenced in 1658, and completed in 1659, according to the separate testimony of Boyle (New Experiments, &c., touching the Spring and Weight of the Air, written in 1659, published in 1660, *Birch's Boyle*, vol. i., p. 7), and *Hooke* (*Waller's Life of Hooke*, p. iii.). The first English air-pump, which may be dated from 1659, had a single brass barrel about 14 inches in length, and 3 in internal diameter. It stood upon a strong wooden tripod, with its mouth turned downwards. The piston or sucker was solid. The shank or piston-rod had teeth cut on it, so as to form a rack, and was moved by a toothed wheel or pinion working into the rack, and turned by a handle, as in the air-pumps of the present day. A hole was bored in the side of the upper end of the cylinder, provided with a ground brass plug or stopper, which could be drawn out or pushed in by the hand. This was the only valve in the engine. The object of the inversion of the cylinder, was to allow the globular or pear-shaped glass receiver, from which it emptied the air, to be placed in a vertical position above the pump.

The receiver had a large opening at the top for inserting objects into it. The opening could be narrowed by a tight-fitting broad brass ring, in the centre of which was an aperture provided with a brass stopper to close it. The receiver terminated below in a narrow neck cemented into a brass stop-cock, which was ground to fit an opening in the upper end of the cylinder, near to the valve in it.

In using the pump to exhaust, the piston was first made to ascend or driven home, whilst the valve in the cylinder was open, and the stop-cock of the receiver shut. The valve was then closed by its stopper or plug, the stop-cock opened, and the piston drawn down. The stop-cock was then closed a second time, the valve opened, and the rarefied air which had entered the cylinder from the receiver, expelled from the former by the second ascent of the piston, and so on *ad infinitum*.

By reversing the order in which the valve and stop-cock were closed and opened, the pump could be made to condense instead of rarefying the air of the receiver. The valve for that purpose was opened, whilst the stop-cock was shut, and the piston drawn down so as to allow the cylinder to be filled with atmospheric air. The valve

was then shut, the stop-cock opened, and the piston as it ascended condensed the air into the receiver.

The most important points to be noticed about the earliest English air-pump, are, that it was provided with one barrel and a manual valve, and that, unlike any later air-pump, the cylinder and receiver were directly connected. The designation by which Boyle preferred to distinguish his machine, was "Pneumatical Engine," and he called it, in contradistinction to his later air-pumps, the "Great Pneumatical Engine." It was presented to the Royal Society immediately after its incorporation in 1662, and Boyle desisted from pneumatic researches for some six or seven years.

In 1667 he constructed his second pneumatical engine, as appears from a letter dated, 24th March of that year, and published at Oxford in 1669, with the title, "A Continuation of New Experiments, &c., &c., touching the Spring and Weight of the Air, in a letter to Lord Dungarvan." Several persons supplied him with suggestions in the way of improvements, of whom, however, he mentions the name only of Hooke.

The second pneumatical engine did not resemble the first in appearance, but, like it, had a single brass barrel. This stood with its mouth upwards, in a large wooden box or trough, filled with water, which rose above the mouth of the cylinder, so that the latter was entirely under water. The object of this arrangement was to keep the leather of the sucker or piston always wet, and therefore "turgid and plump," so as to move air-tight in the barrel. The latter had no valve in it. The piston which was moved by a rack and pinion had an aperture passing vertically through it, which was closed and opened alternately, by thrusting in and pulling out a long stick managed by the hand of the operator. But the great improvement and peculiarity in the engine was, that the receiver was not directly attached to the pump. A tube, provided with a stop-cock, passed from the upper part of the side of the cylinder, in a horizontal direction along a wooden board covered with a thick iron plate, and was then bent up so as barely to project through the iron. The receiver was no longer a globe or pear-shaped vessel, but a bell-shaped hollow glass jar, which was turned with its mouth downwards, like an inverted drinking-glass, and, to use Boyle's homely but expressive phrase, "whelmed on upon the plate, well covered with cement." This arrangement of an air-pump plate, and detached bell-jar receiver,

has been retained in all later air-pumps. In using the pump, the piston, with the aperture in it open, was forced to the bottom of the cylinder. The stick was then thrust into the hole in the piston, and the latter drawn up. It ascended lifting the water with it, and leaving a vacuum below. When the piston had risen above the mouth of the tube communicating with the receiver, the stop-cock was opened, and the air of the receiver allowed to expand into the cylinder. The stop-cock was then shut, the stick pulled out of the aperture in the piston, and the latter forced to the bottom of the cylinder. The air bubbled up through the aperture, and when it had escaped, the stick was inserted into the hole in the piston, and the manipulations proceeded as before. If the stop-cock were opened, as it was liable to be, at the wrong stroke, the receiver, instead of being emptied of air, was filled with water.

Six or seven years again elapsed, without any further improvement being effected on the English air-pump. In 1676, the celebrated and ingenious Frenchman, Denis Papin, came to England, bringing with him a novel pneumatic engine, and became Boyle's assistant. An engraving and description of Papin's air-pump are given in Boyle's tract entitled "A Continuation of New Experiments, &c., touching the Spring and Weight of the Air, and their effects. *Second Part.*"—(*Birch's Boyle*, 2d Ed., vol. iv., p. 505.) The great peculiarity of Papin's air-pump, as contrasted with former air-pumps, was, that it had two barrels, but it had other distinctive arrangements, which makes it singular that it should have been overlooked by later writers on Pneumatics.

It had two pumps standing side by side, the mouths of the barrels being turned upwards. Each of the piston-rods terminated in a stirrup attached to its upper end, and the stirrups were connected by a rope or cord, which passed over a vertical grooved wheel or large pulley. To work the machine, the exerciser of the pumps, as he is called in the original account, put his feet into the stirrups, and holding on, as it should seem, by his hands to the upper part of the framework of the air-pump, or leaning against it (for the description is not precise on this particular), moved his feet alternately up and down as a handloom weaver does, or a culprit on the treadmill. The pistons or suckers had valves (probably of bladder) opening upwards like that of an ordinary water-pump, and similar valves were placed at the bottom of the cylinders, which were filled with water to a certain

height, that the pistons might move air-tight in them. From the cylinders, tubes passed to a common canal, terminating in the air-pump plate, on which receivers to be exhausted were laid, as in Boyle's second engine.

It is not a little singular that Papin's machine should have been overlooked by most later writers. It is not referred to in any recent English work of authority, although its curious stirrup arrangement, which has been employed in no English air-pump, might have been expected to direct attention towards it. Papin is mentioned incidentally by Nairne as an improver of the air-pump.—(*Phil. Trans.*, 1777, p. 635.) Dr Hutton, in his Mathematical Dictionary (vol. i., p. 55, 1796), mentions Papin's two barrels and twin pistons, but not the stirrup arrangement. In Shaw's abridged Boyle, the whole machine is described and figured, but Papin's name is not mentioned.

Recent writers on Pneumatics having overlooked Papin's machine, whilst they universally acknowledge the importance of two barrels with the pistons counterbalancing each other, have attributed this great improvement to Boyle, to Hooke, or to Hauksbee.

Boyle's imputed claim to the honour of having first constructed a double-barrelled air-pump, may be summarily dismissed, as he himself disavows the honour, refers to Papin's air-pump as new to him, and ascribes its invention to Papin.—(*Birch's Boyle*, vol. iv., p. 506.) Mr Weld, however, puts Boyle's claim on another, and at first sight apparently satisfactory, basis. The Royal Society, according to the former, who is its assistant-secretary, possesses Boyle's original air-pump, which has two barrels, and otherwise much resembles an air-pump of the present day.—(*History of Royal Society*, vol. i., p. 96.)

If, however, the instrument shewn to visitors to the Royal Society's apartments, be the earliest English air-pump, then Boyle was not only the first to employ a double-barrelled pneumatic pump, but his earliest pneumatical engine had two barrels. The instrument, however, which, as Boyle informs us ("Continuation of New Experiments, &c., on the Spring and Weight of the Air," Oxford, 1669, Preface), he gave to the Royal Society, in 1662, was his "Great Pneumatical Engine," which he described and figured in 1659. It had a single barrel, and was quite unique in its construction and appearance. The first double-barrelled air-pump to which Boyle refers is Papin's, with which he did not become acquainted till some seventeen years after he presented his earliest air-pump to the Royal

Society. Mr Weld, therefore, is certainly mistaken in conceiving that the old double-barrelled pump in the Society's possession is Boyle's original air-pump. It is probably not an instrument of Boyle's century.

Dr Thomas Young also supposes the first English air-pump to have had two barrels, and ascribes their introduction to Hooke.—(*Natural Philosophy*, Kelland's edition, p. 278.) The latter, however, states distinctly, that the instrument he made for Boyle had one barrel (*Waller's Life of Hooke*, p. iii.), and his drawing of it, which is engraved in the vignette frontispiece on the title-page of the several volumes of Birch's Boyle, represents the great pneumatical engine as possessing but one cylinder. Professor Robison, in his treatise on Pneumatics, ascribes the double pump in one place to Hooke (*Enc. Brit.*, 7th Ed., p. 80), and in another to Hauksbee (p. 93). Professor Robison does not refer to any writing of Hooke's as containing a claim, on his part, to the invention in question; and it is impossible to suppose that Hooke could have constructed a double air-pump before Papin did, without Boyle being aware of the circumstance. At all events, till it is shewn that Hooke himself claimed the double air-pump as his invention, it is unnecessary to discuss his supposed merits as its inventor.

Hauksbee appears to have been the first Englishman who constructed an air-pump with two barrels. He described it in his Treatise entitled "Physico-Mechanical Experiments on various subjects, by Francis Hauksbee, F.R.S., 1709." It was constructed in, or about, 1704, so that it cannot come into competition with a double air-pump of Hooke's invention (if he ever devised one), seeing that he died in 1702. Still less can it supplant Papin's instrument, which was brought to England in 1676, and must have been known to Hauksbee.

Hauksbee's air-pump was a combination of the rack and pinion of Hooke's pneumatical engine which he constructed for Boyle, and the two barrels, twin pistons, and self-acting valves of Papin's pump.

From all, it appears, that no English claimant, at least, can dispute priority, so far as the double pump is concerned, with Papin. Winkler, who was Professor of Natural Philosophy at Leipsic in the middle of last century, in his Sketch of the History of the Air-Pump, refers to Hauksbee's as the first constructed with two barrels. —(*Elements of Natural Philosophy*, 1757, English Translation,

p. 119.) M. Libes (*Histoire Philosophique des Progrès de la Physique*, Paris, 1810–1812), mentions Papin and Hauksbee as the only claimants of the double pump (t. iii., p. 56); and adds, that Cotes, the mathematician of Cambridge, who was contemporary with Hauksbee, regarded Papin as the author of the invention. If there are no claimants known even to Continental historians of science, but Hauksbee and Papin, the latter, whose instrument was constructed more than twenty years before Hauksbee's, is entitled to the whole honour due to the inventor of the double air-pump.

2. On the Classification of Colours. Part II. By Professor J. D. Forbes. (See p. 190.)

The object of this paper is chiefly one of nomenclature. Every one has felt the difficulty of describing with the precision the innumerable hues which occur in nature and in art; and which it is equally desirable for the optical philosopher, the artist, and the manufacturer, to be able to refer to in a clear and definite manner. But such a nomenclature or classification must proceed upon some admission as to the manner of compounding complex hues out of simple ones; and, therefore, the author first treats of the (so-called) Primary Colours. He admits it as highly probable, that all known colours may be formed out of Red, Yellow, and Blue; although, when we attempt to compound pigments, we have a very notable loss of light, and also an unavoidable impurity, which is most visible in the compound tints. The author, in passing, endeavours to explain clearly why the union of pigments never can produce a perfect white, although the coloured light of the spectrum does so; for, by adding blue light to yellow light, we not only change the colour, but we increase the illumination; whereas, by adding a blue to a yellow pigment, whilst we change the colour, we at the same time reduce the luminousness of the surface, the blue particles being far less reflective than the yellow ones. Inferring from Newton's empirical rule, the quantities of red, yellow, and blue light, which should combine to make white light; and adopting Lambert's results as to the reflective powers of the brightest pigments, the author concludes, that the mean illumination of a disk put in rapid revolution, and containing coloured sectors, will be 4·57 times *less* than if it reflected the whole incident light, or it will reflect only about *half* the light which white paper does under the same

illumination, therefore it will appear relatively *grey* under any given external illumination.

The author then states, that the triangular arrangement of colours first proposed by Mayer, and farther carried out by Lambert, appears to afford the clearest and truest mode of displaying at a glance the modification of colour due to the varying proportion of the three primary elements. In this triangle, perfect red, yellow, and blue, occupy the three corners; and these colours graduate into one another, according to the simple law of the distance of any point in the triangle from the three corners. The sides of the triangle are occupied by binary colours or compounds, by two and two; the interior is occupied by triple compounds; and the centre of gravity of the triangle ought to be a neutral grey.

Hence it will appear, that any hue not purposely diluted with black or white, as composed of a compound of a binary colour with neutral grey. Hence a convenient nomenclature suggests itself as follows: the first column containing the binary colours.

RED.	Greyish Red.	Grey Red.	Red Grey.	Reddish Grey.	Grey.
Orangish Red,	*	*			
Red Orange,	*	*	*		
Reddish Orange,	*	*			
ORANGE.	Greyish Orange.	Grey Orange.	Orange Grey.	Orangish Grey.	Grey.
Yellowish Orange,	*	*			
Yellow Orange,	*	*	*		
Orangish Yellow,	*	*			
YELLOW.	Greyish Yellow.	Grey Yellow.	Yellow Grey.	Yellowish Grey.	Grey,
&c.	&c.	&c.	&c.	&c.	&c.

These colours are supposed to be of the standard or maximum attainable intensity.

They may be diluted with white on the one hand, forming *tints;* or with black, forming *shades*.

Mayer's triangle may be repeated with these modifications; but as the colour tends to extinction, either in the direction of perfect blackness or perfect whiteness, the number of compartments in the triangles may be diminished as the dilution of the colours increases. Thus, the whole may be formed into a double pyramid of colour, converging to white above and to black below.

The author has been much indebted to Mr D. R. Hay, the ingenious author of the "Nomenlature of Colours," and other works, not

only for specimens of coloured papers formed by the actual mixture of the three primary colours, but also for many valuable suggestions, of which, in the course of this paper, he has freely availed himself.

It is the author's wish to be able to obtain a series of coloured enamels complete, according to Mayer's and Lambert's classification. Some he has already obtained from the Vatican Collection (of which he gives a short description), and he hopes to render it more complete.

3. Verbal Notice of Siliceous Stalactites on Arthur's Seat. By Dr Fleming.

Dr Fleming began by stating, that a paper of his, "On the Neptunian formation of Siliceous Stalactites," was read before the Society, March 7, 1825, and published in "Brewster's Journal of Science," for April of the same year, p. 307. To this paper Dr Hibbert has referred, in his description of the "Limestone of Burdiehouse," *Edin. Phil. Trans.*, vol. xiii., p. 280, but has misrepresented, in an unaccountable manner, the facts which had been stated. Dr Fleming, expressly said, in describing a limestone containing the remains of dicotyledonous plants, and consisting of flinty and calcareous layers, that it "*dips under* the great bed of limestone belonging to the coal formation which extends north towards Linlithgow," which "encloses the remains of those marine animals which are common in the limestones of the coal formation." Dr Hibbert, on the other hand, confounds the two beds, or rather represents the bed with the vegetable remains as having been viewed as identical with the bed of limestone with marine remains; for he adds, "Dr Fleming's remark, that this limestone encloses the remains of those marine animals, which are common in the limestones of the coal formation, I consider as a mistake." The limestone, however, with vegetable remains, had been described as differing in structure, and occupying a lower position, than the limestone with marine remains.

Dr Fleming then stated that, in the paper referred to, he had described siliceous stalactites as occurring in the trap-rocks of the north side of Fife (a prolongation of the Ochils), and for some time looked for similar concretions, in vain, in the corresponding rocks of Arthur's Seat. Lately, however, he had detected them, hanging from the under surface of a bed of porphyry interstratified with laminated clay, at the Bog-Crag on the east side of the Hunter's Bog. The aqueous origin of the stalactites would not now be disputed, nor, in the present state of chemistry, would their occurrence excite surprise.

The following Donations to the Library were announced:

The Quarterly Journal of the Chemical Society. No. 4. 8vo.—*By the Society.*

Railway Economy: An Exposition of the advantages of Locomotion by Locomotive Carriages, instead of the present expensive system of Steam Tugs. By Lewis Gordon, C. E. 8vo.—*By the Author.*

Transactions of the Royal Scottish Society of Arts. Vol. III., Parts 2 and 3. 8vo.—*By the Society.*

Monday, 5th February 1849.

Sir T. MAKDOUGALL BRISBANE, Bart., President, in the Chair.

The following communications were read:—

1. On some peculiar Impressions on the Surface of certain Strata of Greywacké Schist, at Goldielands, in Roxburghshire. By James Elliot. Communicated by David Milne, Esq.

After some prefatory remarks on the general character of the greywacké formations in the south of Scotland, on their entire destitution of organic remains, or even decided impressions, and on the general prevalence of marks, produced apparently by shallow water, a singular series of schistose strata is described, of little more than two feet in thickness altogether, presenting everywhere peculiar features. First, there are two opposed surfaces, the one sprinkled over with thin, short, raised streaks, and the other with small cylindrical grains, all lying perfectly parallel to each other, and consisting of a hard substance, differing from the material and colour of the greywacké rocks. Next, there are a few seams of fine schist, and then a surface, covered with minute, sharply-defined indentations, having every one a lip turned up on one side, and sometimes clinging to the lip, a small speck of the same hard brown substance, which appears on the two surfaces first mentioned. The lips are invariably on the same side of the indentations, giving the surface the appearance of a farrier's rasp; and the uniform direction in which the lips are thrown out from the indentations, is exactly parallel to the streaks and grains first described. At right angles to that direction are narrow undulating ridges, such as would be produced by a

cutting wind on a tenacious surface. The marks are preserved by a very thin coating of fine earth, and the opposite surface is not a counter-impression, but has peculiarities of its own. After the intervention of a few other seams, there follow repetitions of those already described, but somewhat varied. In conclusion, an explanation of all the appearances is attempted. The author suggests that they have been caused by showers of sand, driven by a strong wind upon the surface of the rocks before they had become hardened. The sand, he supposes, has been derived from volcanoes in activity at the period, and the existence of which is inferred by the igneous character of many of the neighbouring hills.

2. On the Causes of Local Peculiarities of Temperature in different parts of Great Britain. By James Elliot. Communicated by David Milne, Esq.

Many remarkable diversities of temperature are observed in this island, which have not yet been satisfactorily accounted for, either by difference of latitude or of elevation, by shelter or exposure, or by the influence of currents in the ocean. It is attempted to shew that other causes usually assigned have no validity,—that the proximity of high, and consequently cold mountains, has no effect in cooling the low ground near them, even when their summits are covered with perpetual snow, and that a difference in the clearness of the sky, or in the radiating power of the surface of the ground, produces no effect on the average temperature. The great cause, then, of the diversities in question is to be found, the writer considers, in the latent heat of vapour,—in the caloric disengaged by its condensation, or absorbed in its formation. He shews the great addition which may be made to the temperature of the atmosphere by a heavy fall of snow to the windward, and, on the other hand, the great loss of temperature by evaporation. The differences, in the amount of rain, he attributes almost entirely to the general slope of the surface over which the wind passes, in connexion with the height of the ground over which it has previously passed, and the differences of evaporation to the material of the soil and its covering, and to its state of drainage, natural or artificial. Some experiments are then detailed, shewing the amount of moisture capable of being retained by various coverings of soil, moss, &c., and the extent to which some of these promote evaporation. The writer con-

cludes by shewing the great improvement which may be made in the general climate of this island, and particularly in that of its mountainous districts, by complete draining.

3. Verbal Notices. By Dr Fleming.

1. *On the Shell referred to by Ure in his "History of Rutherglen and Kilbride," as "a species of Patella."*—Dr Fleming called the attention of the Society to the extraordinary merits of Mr Ure, who died in 1798, leaving a memorial, in the work above referred to, and which was published at Glasgow in 1793, of an acquaintance with organic remains unequalled on the part of any contemporary author of the United Kingdom. This work, however, is very seldom referred to by modern palæontologists, although eminently useful in illustrating the progress of discovery. It was likewise stated, that an additional degree of interest must be felt by the members of the Society, in consequence of a collection of organic remains, chiefly marine, and from the carboniferous limestone, which belonged to Mr Ure, having been presented by Mr Stark, and which now occupies a place in the cases up stairs.

Dr Fleming stated, that the description of the Patella, referred to at p. 305, and delineated in Tab. xv., figs. 9, 10, is so obscure, doubtless in consequence of the imperfect specimen then in Ure's possession, that it was not until he had succeeded in procuring examples in nearly the same condition, along with others more characteristic, that he could refer the organism to its type, or, rather to the genus DISCINA of Lamarck. This genus was unaccountably confounded with *Orbicula* of Lamarck, by Mr G. B. Sowerby, in a paper in the thirteenth vol. of Linn. Trans., 465, and the errors there introduced have been propagated in the "Silurian System" of Murchison; the "Geology of Yorkshire," by Phillips; and the "Geological Report on Londonderry," &c., by Portlock. The species indicated for the first time by Ure, is probably referable to the *Orbicula rugata* of the Silurian System, p. 610, T. v., f. 11, although much doubt must rest on the determination. The shell consists of several somewhat easily separable layers. The external one, cuticle-like, exhibits regular concentric grooves, constituting the character of the *O. rugata,* while in the different aspects of the inferior layers, may be contemplated the *O. nitida* of Phillips, and the *O. striata* of Sowerby. At the period when Ure wrote he seems to have been in possession of only imperfect examples, or the upper valve of this BRACHIOPOD, but in his col-

lection now on the table there are good specimens of the lower valve, as well as characteristically-marked upper ones.

2. *On the "Fossil Echini" of Ure.*—Dr Fleming stated, that having found plates of Ure's Echinus in company with fragments of spines, with proximal extremities, similar to the figure, Tab. xvi., f. 8, and the distal denticulated extremities conjoined, he had characterised the species in his " British Animals," denominating it CIDARIS *Urii*, thereby commemorating the labours of the discoverer. Captain Portlock, in the work already reported, has described and figured portions of, apparently, the same species, as CIDARIS *Benburbensis*, manufacturing new species besides, without being aware of the differences in the form of the spines, as well as in the sculpture of the plates, from different parts of the crust; truths illustrated by the existing British CIDARIS *papillata*, giving evidence to the palæontologist of the expediency of combining a knowledge of recent with extinct forms. Dr Fleming concluded this notice with stating that he found, during last autumn, the remains of this carboniferous limestone organism in the lowest bed of the old red sandstone series, on the Berwickshire coast, in which he detected marine remains, beginning at the fundamental *conglomerate*, where it rests on the " Transition Rocks" at the Siccart Point, and proceeding westward to Dunbar.

4. Notice by Professor Piazzi Smyth of Locke's Electric Observing Clock.

This instrument, which has been invented in America, consists of an electro-magnetic machine, which, being placed in connection with an ordinary astronomical clock, does not interfere with the regularity of its going, while it marks the instant of each vibration of the pendulum on a revolving cylinder, whose circumference moves at the rate of one inch per second. Two wires being then taken to an observer at any distance, if he, when he observes a star crossing the meridian-wire of his telescope, makes contact with the wires, that moment is immediately marked on the same moving cylinder where the even seconds are registered. The fraction of a second may be then obtained with as much accuracy as the space of an inch may be subdivided by ordinary mechanical means : say to the hundredth of a second. This method is further available in many cases where the present mode of noting transits is not, and admits of a great multiplication of observations during the short space of time that the star occupies in crossing the field of view.